gastroenterology insights

MDPI

Article

Robotic Platform da Vinci Xi Is Feasible and Beneficial in Both Colon and Rectal Surgery in Short-Term Outcome and Recovery

Yi-Lin Huang, Ming-Cheng Chen and Feng-Fan Chiang *

Division of Colorectal Surgery, Department of Surgery, Taichung Veterans General Hospital, 1650 Taiwan Boulevard Section 4, Taichung 40705, Taiwan; omega.yilin@gmail.com (Y.-L.H.); claudiochen7@gmail.com (M.-C.C.)

* Correspondence: hankel.chiang@gmail.com; Tel.: +886-4-2359-2525 (ext. 5161) or +886-919-710-446; Fax: +886-4-2359-5046

Abstract: Background: The literature discussed colorectal surgery using a robotic platform, which is mainly the previous da Vinci Si system. The role of the da Vinci Xi surgical system remains unclear. This study aims to evaluate the benefits and feasibility of using the robot-assisted method in colorectal surgery. Methods: We retrospectively collected 418 patients undergoing minimally invasive colorectal surgery between March 2020 and December 2021, in a single center. Patients were divided into robotic and laparoscopic groups. Primary outcomes were conversion rates to open surgery, complications, and length of stay (LOS). Secondary outcomes were post-operation functional outcomes. Results: A total of 218 patients received colectomy, while 200 patients received rectum resection. No differences were found in the conversion rate in both groups. A lower complication rate (colectomy: 7.5% vs. 23.2%, $p = 0.01$, rectum resection: 14.1% vs. 28.7%, $p = 0.038$) and shorter LOS (5 vs. 8 days, $p < 0.001$) was found in the robotic group. The robotic approach was associated with good functional outcomes in tolerated solid food and the termination of urinary drainage. Conclusions: The new da Vinci Xi system is safe and feasible both for colonic and rectal surgery, with reduced complications. Shorter LOS and reliable short-term outcomes may reflect both better functional recovery and surgical quality when compared to laparoscopic surgery.

Keywords: robotic-assisted surgery; laparoscopic surgery; colectomy; rectum resection; colorectal surgery; complication; functional recovery; length of stay

check for updates

Citation: Huang, Y.-L.; Chen, M.-C.; Chiang, F.-F. Robotic Platform da Vinci Xi Is Feasible and Beneficial in Both Colon and Rectal Surgery in Short-Term Outcome and Recovery. *Gastroenterol. Insights* **2023**, *14*, 538–552. https://doi.org/10.3390/gastroent14040038

Academic Editors: Diego Coletta and Andrea Balla

Received: 13 September 2023
Revised: 16 October 2023
Accepted: 1 November 2023
Published: 6 November 2023

Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Background

Since laparoscopic colorectal surgery was introduced in the 1990s [1], it has gradually changed the way of handling colorectal surgery throughout the past three decades. Currently, laparoscopic colorectal surgery is accepted as a safe and minimally invasive procedure that has been supported by several large-scale randomized clinical trials (RCTs) which have reported convincing oncologic results and long-term outcomes [2–5]. In difficult rectal surgery, as a result of limitations in laparoscopic instruments, the introduction of robotic-assisted colorectal surgery [6,7] has provided 3D images, enhanced instrumental movements in the confined pelvic field, and the stabilization of tremors [8–10].

Currently, the da Vinci Si surgical system (Intuitive Surgical, Inc., Sunnyvale, CA, USA) remains the primary robotic platform performed in most study groups. The role of robotic-assisted surgery using the new da Vinci Xi surgical system for colonic resection remains unclear. In this study, we aimed to evaluate the benefits and feasibility of using the robot-assisted method of the da Vinci Xi system for colon and rectal surgery.

2. Materials and Methods

2.1. Patient Selection

We retrospectively collected the data of patients from Taichung Veterans General Hospital between the period March 2020 and December 2021, as the da Vinci Xi system was installed in our hospital in early 2020. Less than five cases had been performed prior to this period. The research program and informed consents were obtained and reviewed from the Institutional Review Board I and II of Taichung Veterans General Hospital (Case No. CE22367A). All experimental protocols were reviewed and approved by the institutional review board. All study methods were carried out in accordance with relevant guidelines and regulations.

2.2. Inclusion and Exclusion Criteria

All patients aged $\geq$ 18 years requiring elective left-sided colectomy (left hemicolectomies, sigmoidectomies, or rectosigmoidectomies) with a minimally invasive approach (robotic-assisted laparoscopy (RAL) or laparoscopy (LSC)) between June 2015 and December 2019 were included in this study. The major indication for surgery was neoplasm, and other diseases (e.g., chronic and recurrent diverticulitis, polyps or polypoid tumor that could not be resected endoscopically, and lipoma) were also included. Tumors graded T4 preoperatively were excluded because we preferred an open approach for large tumors with suspicion of organ infiltration. The retrospective analysis of prospectively collected data was performed at two high-volume, colorectal surgery units. RAL versus LSC was chosen according to instrument availability and surgeons' preference, with no specific selection criteria. All patients were preoperatively informed about the surgical technique.

All patients who received robotic-assisted colorectal surgery were enrolled. Robotic-assisted surgery was carried out using the da Vinci Xi surgical system. Any patients who underwent laparoscopic colorectal surgery during the same period were also collected for comparison. A total of eight senior institutional board-certified colorectal surgeons in our department performed laparoscopic surgery, and three out of these eight surgeons conducted robotic surgery. Laparoscopic surgery was established decades ago in our hospital, and all participating surgeons had to perform a minimum of 100 laparoscopic surgeries

2.3. Robotic Technique

Surgical procedures used in the colectomy group included right hemicolectomy (RH), left hemicolectomy (LH), anterior resection (AR), and subtotal colectomy. Rectal resection was defined as a lesion situated within 15 cm from the anal verge. Patients who received low anterior resection (LAR) and abdominoperineal resection (APR) were included in the rectum resection group.

For left-side colectomy (LH and AR) and rectum resection, without an integrated table motion device, we used the single docking method on a docking patient cart. After the patient was placed in the right-side-down Trendelenburg position, the cart was docked on the left caudal side. We mobilized the colon using the medial-to-lateral approach, which started with an incision of the peritoneum. The inferior mesenteric artery (IMA) was divided and ligated using a hemo-clip. The subsequent medial-to-lateral extension was completed along the avascular portion to detach the mesocolon from the retroperitoneal, ureter, and gonadal vessels until it reached the left paracolic gutter. In case of a low anterior reaction, the procedure was carried out on the pelvic floor, where the sympathetic and parasympathetic nerves were spared. A robotic stapler was used to divide the sigmoid colon or rectum. A para-umbilical incision was then made to extract the specimen and prepare it for anastomosis. In those patients who received APR, the specimen was retracted from the anus.

For RH, the same single docking method was used but, in the left-side-down Trendelenburg position, with the patient cart docked on the right caudal side. The procedure began with the entry into the retroperitoneum in the avascular portion of the peritoneum at the root of the ileocolic vessels. After isolating and dividing the ileocolic vessels by using a hemo-clip and vessel sealer, the mesentery of the right colon was mobilized from medial to lateral, leaving behind the ureter, duodenum, and retroperitoneal structures. The omentum was then opened to enter the lesser sac and complete mobilization of the right colon after taking down the hepatic flexure. A para-umbilical incision was made to extract the specimen and prepare for anastomosis. In right-side colectomy, instead of using a circular stapling device, we used a linear stapling device to perform side-to-side anastomosis.

2.4. Evaluation of Surgical Outcomes

Patient characteristics including age, gender, body mass index (BMI), diabetes, smoking status, history of abdominal or pelvis surgery, preoperative chemotherapy, preoperative pelvic radiation therapy, and American Society of Anesthesiologists (ASA) class were all collected and evaluated. Surgical time, estimated blood loss, rate of conversion to open surgery, and pathology outcome were all collected.

Primary outcomes were the conversion rate to open surgery, 30-day complications, and length of stay (LOS). Secondary outcomes were postoperative functional outcomes. Overall complications included both surgical and nonsurgical issues, with surgical complications including ileus, anastomotic leak, and wound infection, whereas nonsurgical complications included cardiovascular and pulmonary complications, urinary tract infections, and acute kidney injury. Postoperative complications were graded using the Clavien–Dindo classification [11]. Those complications not requiring surgical or radiological intervention were graded as either 1 or 2, whereas those requiring intervention were graded as 3.

2.5. Statistical Analysis

Groups were compared using *t* tests and Mann–Whitney U tests for continuous outcomes given the lack of normality. Chi-square and Fisher's exact tests for categorical variables were used when appropriate. Statistical analyses were performed with IBM SPSS version 22 software (SPSS Inc., Chicago, IL, USA). Significance was set at $p < 0.05$.

3. Results

A total of 418 patients undergoing elective colorectal resection were included for analysis, of which 131 were robotic and 287 were laparoscopic. Groups were stratified by type of surgical approach and type of minimally invasive surgery. A total of 218 patients received colon resection (including RH, LH, and AR), among which, 67 received robotic-assisted colectomy, and 151 received laparoscopic colon resection surgery. There were 200 patients who received rectum resection, with 64 receiving robotic-assisted LAR and 136 receiving laparoscopic LAR. Basic characteristics are demonstrated in Table 1.

Table 1. Patient characteristics.

	Colectomy					Rectum Resection (LAR)				
	Laparoscopic (n = 151)		Robotic Xi (n = 67)		*p* Value	Laparoscopic (n = 136)		Robotic Xi (n = 64)		*p* Value
Sex					0.856					0.053
Female	64	(42.4%)	30	(44.8%)		41	(30.1%)	29	(45.3%)	
Male	87	(57.6%)	37	(55.2%)		95	(69.9%)	35	(54.7%)	
Age	65.0	(57.0–71.0)	62.0	(52.0–71.0)	0.212	66.0	(57.0–73.8)	56.0	(47.3–65.8)	<0.001 **
Age group					0.293					<0.001 **
<55	32	(21.2%)	21	(31.3%)		26	(19.3%)	28	(43.8%)	
56–64	37	(24.5%)	18	(26.9%)		33	(24.4%)	19	(29.7%)	
65–74	54	(35.8%)	17	(25.4%)		45	(33.3%)	11	(17.2%)	
>75	28	(18.5%)	11	(16.4%)		31	(23.0%)	6	(9.4%)	
BMI	24.5	(22.5–27.0)	24.2	(22.1–26.9)	0.755	24.3	(22.1–26.0)	24.0	(21.6–26.7)	0.862
BMI group					0.417					0.649
Under weight	1	(0.7%)	2	(3.0%)		1	(0.7%)	1	(1.6%)	
Normal weight	66	(43.7%)	26	(38.8%)		66	(48.5%)	31	(48.4%)	
Over weight	45	(29.8%)	24	(35.8%)		45	(33.1%)	17	(26.6%)	
Obese	39	(25.8%)	15	(22.4%)		24	(17.6%)	15	(23.4%)	
Smoking					0.430					0.443
N	125	(82.8%)	59	(88.1%)		114	(83.8%)	57	(89.1%)	
Y	26	(17.2%)	8	(11.9%)		22	(16.2%)	7	(10.9%)	
Diabetes					0.877					0.111
N	118	(78.1%)	51	(76.1%)		109	(80.1%)	44	(68.8%)	
Y	33	(21.9%)	16	(23.9%)		27	(19.9%)	20	(31.3%)	

Table 1. *Cont.*

	Colectomy					Rectum Resection (LAR)				
	Laparoscopic (n = 151)		Robotic Xi (n = 67)		*p* Value	Laparoscopic (n = 136)		Robotic Xi (n = 64)		*p* Value
Previous surgical history of the abdomen					0.470					0.001 **
N	123	(81.5%)	51	(76.1%)		127	(93.4%)	48	(75.0%)	
Y	28	(18.5%)	16	(23.9%)		9	(6.6%)	16	(25.0%)	
ASA physical status					0.483					0.525
1	16	(10.6%)	10	(14.9%)		22	(16.2%)	7	(10.9%)	
2	100	(66.2%)	39	(58.2%)		90	(66.2%)	44	(68.8%)	
3	35	(23.2%)	18	(26.9%)		22	(16.2%)	13	(20.3%)	
4	0	(0.0%)	0	(0.0%)		2	(1.5%)	0	(0.0%)	
Pre-OP Chemotherapy					--					0.001 **
N	151	(100.0%)	67	(100.0%)		111	(81.6%)	37	(57.8%)	
Y	0	(0.0%)	0	(0.0%)		25	(18.4%)	27	(42.2%)	
Pre-OP Radio therapy					--					<0.001 **
N	151	(100.0%)	67	(100.0%)		112	(82.4%)	34	(53.1%)	
Y	0	(0.0%)	0	(0.0%)		24	(17.6%)	30	(46.9%)	

Chi-square test or Mann-Whitney U test, Median (IQR). ** $p < 0.01$.

3.1. Colectomy Cohort

In the colectomy cohort, we found no significant baseline characteristic differences between the robotic-assisted and laparoscopic approaches in age, BMI, abdominal surgery history, preoperative chemotherapy, and preoperative radiotherapy. The median BMI was 24.2 in the robotic-assisted group and 24.5 in the laparoscopic group. Robotic-assisted colectomy may result in a higher degree of cancer resection than laparoscopic colectomy (91% in robot vs. 78.8% in laparoscopic, $p = 0.045$). The median operative time was 250 min (range = 225–305 min) in the robotic-assisted group and 160 min (range = 134–208 min) in the laparoscopic group ($p < 0.001$). The average blood loss was 55.5 mL in the robotic-assisted group and 37.6 mL in the laparoscopic group. Although the median number of retrieved lymph nodes was equal to 21, more lymph node involvement was found in the robotic-assisted group than in the laparoscopic group (49.2% in robot vs. 35% in laparoscopic, $p = 0.03$; Table 2).

Table 2. Peri-operative characteristics of colectomy and rectum resection cohort.

	Colectomy					Rectum Resection (LAR)				
	Laparoscopic (n = 151)		Robotic Xi (n = 67)		*p* Value	Laparoscopic (n = 136)		Robotic Xi (n = 64)		*p* Value
Indications					0.045 *					0.334
Benign	32	(21.2%)	6	(9.0%)		6	(4.4%)	5	(7.8%)	
Cancer	119	(78.8%)	61	(91.0%)		130	(95.6%)	59	(92.2%)	
Operation time (mins)	160.0	(134.0–208.0)	250.0	(225.0–305.0)	<0.001 **	223.5	(174.0–293.5)	315.5	(271.3–363.8)	<0.001 **
Consoling time(mins)			125.0	(102.0–169.0)				163.5	(127.0–210.8)	
Blood loss	0.0	(0.0–100.0)	0.0	(0.0–0.0)	0.353	0.0	(0.0–100.0)	0.0	(0.0–37.5)	0.023 *
Ostomy					0.093					0.150
N	151	(100.0%)	65	(97.0%)		63	(46.3%)	22	(34.4%)	
Y	0	(0.0%)	2	(3.0%)		73	(53.7%)	42	(65.6%)	
Number of retrieved lymph nodes	21.0	(15.0–27.0)	21.0	(16.0–27.0)	0.780	21.0	(15.0–25.8)	17.0	(13.0–21.8)	0.003 **
Distal margin (cm)	5.0	(3.0–7.0)	3.5	(2.5–6.0)	0.042	1.7	(1.0–2.8)	2.0	(1.0–2.6)	0.456
CRM					--					1.000
Not involved	151	(100.0%)	67	(100.0%)		127	(93.4%)	60	(93.8%)	
Involved	0	(0.0%)	0	(0.0%)		9	(6.6%)	4	(6.3%)	

Table 2. *Cont.*

	Colectomy					Rectum Resection (LAR)				
	Laparoscopic (n = 151)		Robotic Xi (n = 67)		*p* Value	Laparoscopic (n = 136)		Robotic Xi (n = 64)		*p* Value
T stage					0.064					0.839
Tis	5	(3.3%)	6	(9.0%)		9	(6.6%)	6	(9.4%)	
1	20	(13.2%)	5	(7.5%)		19	(14.0%)	9	(14.1%)	
2	19	(12.6%)	8	(11.9%)		33	(24.3%)	16	(25.0%)	
3	54	(35.8%)	33	(49.3%)		56	(41.2%)	24	(37.5%)	
4	21	(13.9%)	9	(13.4%)		13	(9.6%)	4	(6.3%)	
others	32	(21.2%)	6	(9.0%)		6	(4.4%)	5	(7.8%)	
N stage					0.031 *					0.578
0	93	(65.0%)	32	(50.8%)		79	(58.1%)	38	(62.3%)	
1a	9	(6.3%)	6	(9.5%)		16	(11.8%)	5	(8.2%)	
1b	20	(14.0%)	9	(14.3%)		16	(11.8%)	5	(8.2%)	
1c	1	(0.7%)	6	(9.5%)		3	(2.2%)	4	(6.6%)	
2a	13	(9.1%)	7	(11.1%)		12	(8.8%)	6	(9.8%)	
2b	7	(4.9%)	3	(4.8%)		10	(7.4%)	3	(4.9%)	
M stage					0.512					0.409
0	120	(93.8%)	57	(90.5%)		122	(92.4%)	54	(93.1%)	
1a	6	(4.7%)	4	(6.3%)		9	(6.8%)	3	(5.2%)	
1b	1	(0.8%)	0	(0.0%)		1	(0.8%)	0	(0.0%)	
1c	1	(0.8%)	2	(3.2%)		0	(0.0%)	1	(1.7%)	

Chi-square test or Mann-Whitney U test, Median (IQR). * $p < 0.05$, ** $p < 0.01$.

None of the operations converted to open in the robotic-assisted group, whereas nine patients (6.0%) converted to open in the laparoscopic group(Table 3). No significant differences were found in the re-operation rate within 30 days (1.5% in robot vs. 2.6% in laparoscopic, $p = 1.0$). A lower overall complication rate was found in the robotic-assisted group than in the laparoscopic group (7.5% in robot vs. 23.2% in laparoscopic, $p = 0.01$). Among all the complications, the ileus accounted for the majority of the overall complications in the laparoscopic group (3% in robot vs. 13.2% in laparoscopic, $p = 0.038$). The median length of stay was 5 days (range 4–7 days) in the robotic-assisted group and 8 days (range 6–10 days) in the laparoscopic group ($p < 0.001$). The median time of termination of urinary drainage was 2 days (1 and 2 days) in the robotic-assisted group and 4 days (range 2–5 days) in the laparoscopic group. The median time of tolerated solid food was 2 days (2 and 3 days) in the robotic-assisted group and 4 days (range 3–6 days) in the laparoscopic group ($p < 0.001$).

Table 3. Comparison of outcomes and complication between colectomy and rectum resection cohort.

	Colectomy					Rectum Resection (LAR)				
	Laparoscopic (n = 151)		Robotic Xi (n = 67)		*p* Value	Laparoscopic (n = 136)		Robotic Xi (n = 64)		*p* Value
Convert to Open	9	(6.0%)	0	(0.0%)	0.06	5	(3.7%)	0	(0.0%)	0.179
Overall complications					0.010 *					0.038 *
No	116	(76.8%)	62	(92.5%)		97	(71.3%)	55	(85.9%)	
Yes	35	(23.2%)	5	(7.5%)		39	(28.7%)	9	(14.1%)	
Clavien-Dindo classification					0.927					0.248
1	24	(64.9%)	3	(60.0%)		28	(68.3%)	4	(40.0%)	
2	8	(21.6%)	1	(20.0%)		6	(14.6%)	3	(30.0%)	
3	5	(13.5%)	1	(20.0%)		7	(17.1%)	3	(30.0%)	
Complication										
Anastomosis leakage	3	(2.0%)	1	(1.5%)	1.000	8	(5.9%)	2	(3.1%)	0.507
Chylous leakage	4	(2.6%)	1	(1.5%)	1.000	5	(3.7%)	1	(1.6%)	0.666
Drainage dislodge	1	(0.7%)	0	(0.0%)	1.000	0	(0.0%)	0	(0.0%)	--
Ostomy stenosis	0	(0.0%)	0	(0.0%)	--	0	(0.0%)	1	(1.6%)	0.320
Pneumonia	1	(0.7%)	1	(1.5%)	0.521	1	(0.7%)	0	(0.0%)	1.000
Respiratory compromise	0	(0.0%)	0	(0.0%)	--	2	(1.5%)	0	(0.0%)	1.000

Table 3. *Cont.*

	Colectomy					Rectum Resection (LAR)				
	Laparoscopic (n = 151)		Robotic Xi (n = 67)		*p* Value	Laparoscopic (n = 136)		Robotic Xi (n = 64)		*p* Value
Septic shock	0	(0.0%)	0	(0.0%)	--	1	(0.7%)	0	(0.0%)	1.000
Stoma infection	0	(0.0%)	0	(0.0%)	--	1	(0.7%)	0	(0.0%)	1.000
Ileus	20	(13.2%)	2	(3.0%)	0.038 *	18	(13.2%)	2	(3.1%)	0.049 *
Intra-abdomen infection	0	(0.0%)	0	(0.0%)	--	0	(0.0%)	0	(0.0%)	--
Surgical site infection	0	(0.0%)	0	(0.0%)	--	0	(0.0%)	0	(0.0%)	--
Urinary tract infection	2	(1.3%)	0	(0.0%)	1.000	1	(0.7%)	0	(0.0%)	1.000
Wound dehiscence	3	(2.0%)	0	(0.0%)	0.554	1	(0.7%)	0	(0.0%)	1.000
Re on Foley	19	(12.6%)	7	(10.4%)	0.824	23	(16.9%)	10	(15.6%)	0.980
Tolerate solid food (days)	4.0	(3.0–6.0)	2.0	(2.0–3.0)	<0.001	4.0	(3.0–5.0)	2.0	(2.0–2.0)	<0.001 **
Termination of urinary drainage (days)	4.0	(2.0–5.0)	2.0	(1.0–2.0)	<0.001	5.0	(4.0–7.0)	2.0	(2.0–3.8)	<0.001 **
Re Operation in 30 days					1.000					1.000
No	147	(97.4%)	66	(98.5%)		129	(94.9%)	61	(95.3%)	
Yes	4	(2.6%)	1	(1.5%)		7	(5.1%)	3	(4.7%)	
Readmission					1.000					1.000
No	148	(98.0%)	66	(98.5%)		131	(96.3%)	62	(96.9%)	
Yes	3	(2.0%)	1	(1.5%)		5	(3.7%)	2	(3.1%)	
Length of stay	8.0	(6–10)	5	(4–7)	<0.001	8	(7–11)	5	(4–8)	<0.001 **

Chi-square test or Mann-Whitney U test, Median (IQR). * $p < 0.05$, ** $p < 0.01$.

Logistic regression analysis regarding univariate analysis in the colectomy group revealed a lower OR in overall complication rate, ileus, time to tolerate solid food, termination of urinary drainage, and LOS when compared with the laparoscopic group (Table 4). Tolerated solid food (OR 0.62, CI 0.42–0.90, $p = 0.013$) was considered significant when compared with the laparoscopic group in the multivariable model.

Table 4. Logistic regression of Colectomy (outcome: Robotic).

	Univariate			Multivariable1		
	OR	95% CI	*p* Value	OR	95% CI	*p* Value
Sex						
Female	Reference					
Male	0.91	(0.51–1.62)	0.742			
Age, years	0.99	(0.97–1.01)	0.415			
BMI	0.97	(0.89–1.05)	0.441			
Previous surgical history of the abdomen						
N	Reference					
Y	1.38	(0.69–2.76)	0.366			
Indications						
Benign	Reference			Reference		
Cancer	2.73	(1.08–6.89)	0.033 *	5.24	(1.40–19.62)	0.014 *
Operation time (mins)	1.02	(1.02–1.03)	<0.001 **	1.03	(1.02–1.04)	<0.001 **
Blood loss	1.00	(1.00–1.00)	0.304			
Overall complications						
No	Reference			Reference		
Yes	0.27	(0.10–0.72)	0.009 **	0.61	(0.13–2.98)	0.543
Complication						
Ileus	0.20	(0.05–0.89)	0.034 *			
Re on Foley	0.81	(0.32–2.03)	0.654			
Tolerate solid food (days)	0.49	(0.38–0.63)	<0.001 **			
Termination of urinary drainage (days)	0.69	(0.58–0.83)	<0.001 **			
Re Operation in 30 days						
No	Reference					
Yes	0.56	(0.06–5.08)	0.604			
Readmission						
No	Reference					
Yes	0.75	(0.08–7.32)	0.803			
Length of stay	0.85	(0.76–0.95)	0.004 **	0.83	(0.74–0.94)	0.004 **

Logistic regression. * $p < 0.05$, ** $p < 0.01$.

3.2. Rectum Resection Cohort

In the rectum resection cohort (LAR and APR), no significant difference in baseline characteristics was found between the robotic-assisted and laparoscopic approaches in BMI and abdomen surgery history. The median BMI was 24.0 in the robotic-assisted group and 24.3 in the laparoscopic group. The median age was 56 years (range = 47.3–65.8) in the robotic-assisted group and 66 years (range = 57–73.8) in the laparoscopic group ($p < 0.001$). The median operative time was 315 min (range 271.3–363.8 min) in the robotic-assisted group and 223.5 min (range = 174–293.5 min) in the laparoscopic group ($p < 0.001$). The average blood loss was 72.7 mL in the robotic-assisted group (range = 0–37.5 mL) and 113.6 mL in the laparoscopic group (range = 0–100 mL). The median number of retrieved lymph nodes was 17 in the robotic-assisted group (range = 13–21.8) and 21 in the laparoscopic group (range = 15–25.8; Table 2).

None of the operations were converted to open in the robotic-assisted group, but five cases (3.7%) in the laparoscopic group were converted to open surgery. No significant difference was found in the re-operation rate within 30 days (4.7% in robot vs. 5.1% in laparoscopic, $p = 1.0$). A lower overall complication rate was found in the robotic-assisted group than in the laparoscopic group (14.1% in the robot vs. 28.7% in laparoscopic, $p = 0.038$). Among all complications, the ileus accounted for the majority of the overall complications in the laparoscopic group (3.1% in robot vs. 13.2% in laparoscopic, $p = 0.049$). The median LOS was 5 days (range = 4–8 days) in the robotic-assisted group and 8 days (range = 7–11 days) in the laparoscopic group ($p < 0.001$). The median time of termination of urinary drainage was 2 days (range = 2–3.8 days) in the robotic-assisted group and 5 days (range = 4–7 days) in the laparoscopic group ($p < 0.001$). The median time of tolerated solid food was 2 days (range = 1–3 days) in the robotic-assisted group, and 5 days (range = 2–5 days) in the laparoscopic group ($p < 0.001$) (Table 3).

Logistic regression analysis regarding univariate analysis in the rectum resection group revealed a lower OR in the overall complication rate, ileus, time to tolerate solid food, termination of urinary drainage, and LOS when compared with the laparoscopic group. Tolerated solid food (OR 0.63, CI 0.47–0.85, $p = 0.002$) and the termination of urinary drainage (OR 0.63, CI 0.49–0.82, $p = 0.001$) were considered significant compared with the laparoscopic group in the multivariable model (Table 5).

Table 5. Logistic regression of Rectum resection (outcome: Robotic).

	Univariate			Multivariable		
	OR	**95% CI**	***p* Value**	**OR**	**95% CI**	***p* Value**
Sex						
Female	Reference			Reference		
Male	0.52	(0.28–0.96)	0.037 *	0.87	(0.37–2.05)	0.758
Age, years	0.95	(0.93–0.97)	<0.001 **	0.96	(0.93–0.99)	0.007 **
BMI	1.04	(0.97–1.12)	0.288			
Previous surgical history of the abdomen						
N	Reference			Reference		
Y	4.70	(1.95–11.36)	0.001 **	6.41	(1.84–22.39)	0.004 **
Pre-OP Chemotherapy						
N	Reference			Reference		
Y	3.24	(1.68–6.26)	<0.001 **	0.12	(0.02–0.86)	0.035 *
Pre-OP Radio therapy						
N	Reference			Reference		
Y	4.12	(2.13–7.97)	<0.001 **	23.50	(3.36–164.49)	0.001 **

Table 5. *Cont.*

	Univariate			Multivariable		
	OR	**95% CI**	***p* Value**	**OR**	**95% CI**	***p* Value**
Indications						
Benign	Reference					
Cancer	0.54	(0.16–1.86)	0.331			
Operation time (mins)	1.01	(1.00–1.01)	<0.001 **	1.01	(1.00–1.01)	<0.001 **
Blood loss	1.00	(1.00–1.00)	0.247			
Overall complications						
No	Reference			Reference		
Yes	0.41	(0.18–0.90)	0.027 *	1.54	(0.44–5.37)	0.496
Complication						
Ileus	0.21	(0.05–0.94)	0.041 *			
Re on Foley	0.91	(0.40–2.05)	0.819			
Tolerate solid food (days)	0.46	(0.35–0.61)	<0.001 **			
Termination of urinary drainage (days)	0.57	(0.47–0.69)	<0.001 **			
Re Operation in 30 days						
No	Reference					
Yes	0.91	(0.23–3.63)	0.889			
Readmission						
No	Reference					
Yes	0.85	(0.16–4.48)	0.843			
Length of stay	0.85	(0.78–0.94)	0.001 **	0.80	(0.70–0.92)	0.002 **

Logistic regression. * $p < 0.05$, ** $p < 0.01$.

4. Discussion

In our study, no significant difference was found in the conversion rate, 30-day re-operation rate, and 30-day re-admission rate compared with laparoscopic surgery, either in the colectomy or rectum resection cohort. We found that robotic-assisted surgery showed better results than laparoscopic surgery in overall complications, postoperative functional recovery, and shorter LOS in both the colectomy and rectum resection cohorts. The surgical time necessary for robotic-assisted surgery was still longer than that required for laparoscopic surgery.

Given the anatomical nature of the pelvis, the use of laparoscopic surgery for rectum excision may be confined because of instrument limitation, which causes difficulty during rectum resection. With the introduction of robotic-assisted total mesorectal excision for rectal cancer in 2006 [7], the robotic platform for rectum excision has since become popular because of its advantages, including a stable camera and 3D vision providing a better operational field and use of stabilized and EndoWrist instruments, which can efficiently eliminate tremors in the narrow working space of the pelvis [12].

Although data from the ROLARR trial, the largest RCT to date, did not confirm a certain superior outcome in rectal resection compared with conventional laparoscopic surgery [13], this result is still under debate. This rationale is based upon not only the problem regarding the learning effect [14], but also the difficulty regarding any mechanical limitations, such as the dimensional rotation limit of the formerly used robotic system (the da Vinci Si system) prior to 2014.

Previous use of the robotic platform was restricted due to the limited range of motion of the robotic arms, thereby making multi-quadrant colonic resection difficult to perform [15,16]. The low rectal lesions forced the console to target deep into the pelvis and limited its possibility to achieve spleen flexure; therefore, various methods have been developed such as the hybrid approach and dual docking approach. The new generation of the da Vinci Xi system is equipped with slim arms, extended instrument length, and patient clearance technology to help avoid external collision and extend the working area, thereby making colonic resection more favorable for surgeons compared with previous da Vinci Si system [17–19]. The da Vinci Xi system is superior in terms of the range of motion and is capable of completing the multiquadrant surgery. Protyniak et al. [17] reported using Xi to complete spleen flexure mobilization during low anterior resection in single docking.

4.1. Conversion Rate

The conversion rate can be used as a surgical quality measurement. While experiencing conversion to open surgery, patients may suffer from an increased risk of developing postoperative complications, poor oncological outcomes, and long hospital stays [20,21].

In our study, there was no robotic-assisted surgery converted to open in the colectomy cohort and rectum resection cohort using the pure da Vinci Xi system. In a previous robotic platform using da Vinci Si system era, the largest RCT to date, the ROLLARR trial reported a conversion rate of 12.2% in laparoscopic surgery and 8.1% in the robotic-assisted surgery with no significant statistical difference ($p = 0.16$) [13]. Another nationwide database using the American College of Surgeons National Surgical Quality Improvement Project (ACS-NSQIP) from 2012 to 2014 of patients undergoing colectomies published by Dolejs et al. in 2017 also showed that the conversion rate was lower than that in the rectum resection cohort (robot 6.8% vs. laparoscopic 12.8%, $p < 0.01$) [22].

The reason for the lower conversion rate in the robotic-assisted group than in the laparoscopic group might be due to the da Vinci Xi system's technical and instrument improvements. Such changes help facilitate surgeons' ability to overcome the difficult and challenging operation such as unexpected adhesions or narrow pelvic cavities which often count for important roles of conversion in laparoscopic surgeries. In our hospital, a high-volume medical center in Taiwan, surgeons have experienced at least hundreds of laparoscopic surgeries before ever performing robotic-assisted surgery. In the robotic-assisted group, surgery began with evaluating the abdomen condition using a laparoscope to determine if robotic-assisted surgery was suitable or not before docking the robotic-arm cart. This step would not only protect patients from experiencing conversion to open surgery but also from preventing patients from high costs when using the robotic platform. Furthermore, it is undeniable that surgeons may select easy cases while developing new techniques [23]. Those patients deemed unsuitable for minimally invasive surgery were advised to undergo a conventional type of operation. These factors may be the reasons resulting in low conversion rates for both groups. Two published studies were in agreement with our data of a striking low conversion rate. Panteleimonitis et al. reported a zero-conversion rate in 240 patients by using robotic-assisted surgery in the rectum resection cohort between 2013 and 2016. The team compared the short-term outcomes of robotic rectal cancer resection between the da Vinci Si and Xi systems, but they did not enrol laparoscopic surgery as comparison [24]. Beltzer et al. showed a zero conversion rate using da Vinci Xi for patients with diverticular disease undergoing robotic resection compared with laparoscopic sigmoid resection in 106 patients between 2013 and 2018. Another author attributed the low conversion rate to the advanced instrument improvement [25].

4.2. Complication of the Rectum

The literature showed that the complication rate of the laparoscopic group in the rectum resection cohort ranged from 21.8% to 34.2%, but no significant statistical difference was found between the laparoscopic group and the robotic-assisted group [13,22,26]. In line with the published data, the complication rate of the laparoscopic group in the rectum resection cohort was 28.7%. We found that the overall complication rate of the robotic-assisted group was lower than that of the laparoscopic group (robot 14.1% vs. laparoscopic 28.7%, $p = 0.038$). Crippa et al. reported that robotic surgery had a lower overall complication rate than the laparoscopic group (robot 37.2% vs. laparoscopic 51.2%; $p < 0.001$), and they suggested that robotic surgery is the most protective factor (odds ratio [OR] 0.485; $p < 0.006$) for odds to complications [27]. In the rectum resection cohort, the average age in the robotic group was younger than that in the laparoscopic group by 10 years, thereby influencing the outcome and complications in the rectum group. Many elderly patients could not receive the operation after pre-operative chemo-radiation therapy, causing the age difference between the robotic group and laparoscopic group in the rectum resection cohort. The occurrence of adhesion after abdomen surgery is believed to increase, causing difficulty in future surgery. Surgeons will advise patients to receive conventional operation rather than minimally invasive surgery to avoid complications such as conversion to open surgery and iatrogenic injury during operation. In our study, we took advantage of the robotic instrument, which allowed these patients with a previous history of abdomen surgery to receive minimally invasive surgery. In our study involving the rectal resection cohort, more patients in the robotic-assisted rectal resection group received pre-operation neoadjuvant chemoradiation therapy than patients in the laparoscopic group (42.2% in robot vs. 18.4% in laparoscopic, $p = 0.001$). Given that pre-operation neoadjuvant chemoradiation therapy is an established risk factor for complications, previous studies have not concluded as to whether pre-operation neo-adjuvant chemoradiation therapy affects surgical outcomes [22,27,28]. Our data revealed a lower overall complication rate in the robotic-assisted rectal resection cohort than in the other cohort, even though more patients in the robotic-assisted group received pre-operation neoadjuvant chemoradiation therapy.

4.3. Complication of the Colon

A similar result regarding the lower overall complication rate in the robotic-assisted group was also found in the colectomy cohort (robot 7.5% vs. laparoscopic 23.2%, $p = 0.01$).

A previous meta-analysis of 14 studies involving 4934 patients who received robotic colectomy surgery reported lower complication rates compared with open surgery published in 2016 [29]. Another meta-analysis compared robotic-assisted RH with laparoscopic RH and data from the American College of Surgeons National Surgical Quality Improvement Project (ACS-NSQIP) reported no significant statistical difference compared with laparoscopic RH [22,30]. In our study, the complication rate of the laparoscopic colectomy group (23.2%) was in line with previous studies (19–28.2%), but lower in the robotic-colectomy group (7.5%) compared with previous studies (15.6–26.9%). Among the complications in the laparoscopic colectomy group in our study, the ileus was counted for the majority (13.2%) compared with the robotic-assisted colectomy group (2%). Different generation robotic platforms facilitated easy multiquadrant manipulation of mesocolon and avoided unnecessary intestine traction and tissue trauma, thereby minimizing possible ileus after operation. In our study, we found a higher proportion of Clavien–Dindo classes II and III than Clavien–Dindo class I in the robotic-assisted rectum resection group, but the difference was not statistically significant. No such finding was found in the robotic-assisted colectomy group. We believe that the fundamental nature between colon resection and pelvic surgery caused this difference. Different from the rectum resection cohort, 21% of patients with a benign disease received laparoscopic surgery in the colectomy cohort. This result may be due to the fact that many patients with diverticulitis were enrolled in our colectomy cohort. Diverticulitis is a benign disease that may cause operation challenges such as severe adhesion or even fistula caused by the inflammatory process. Surgeons may face different conditions in patients with colon cancer, such as bulky tumor, enlarged colon caused by tumor obstruction, or tumor infiltration to other organs. Despite facing different surgical conditions, the robotic-assisted colectomy group showed better results than the laparoscopic colectomy group.

4.4. Lymph Node Harvest

In our study, reduced lymph node harvest was observed in the robotic-assisted rectum resection group. However, nearly equal lymph nodes were found between the laparoscopic and robotic-assisted groups in the colectomy cohort. The number of harvested lymph nodes ranged from 15.5 to 31.2 in the colectomy group and from 9 to 14 in the rectum resection group [30,31]. In a previous study of colectomy, concurrent chemo-radiation therapy was found to decrease the number of involved lymph nodes and reduce the recurrent rate [31–33]. This interesting finding may be attributed to more patients having received pre-operation neoadjuvant chemoradiation therapy in the robotic-assisted group in our study. We observed no significant difference in harvested lymph node number between robotic-assisted and laparoscopic surgery, either in colonic resection or rectal resection in the published studies [10,34–37]. However, the mean number of lymph nodes harvested in both groups was higher than the requirement for pathological staging. This finding should be carefully observed to determine whether it influences long-term outcomes in the future.

4.5. Operation Time

Meta-analyses performed over the recent years have shown that robotic-assisted rectum resection surgery demonstrates a longer surgical time than laparoscopic surgery [10,12,36,38–40]. Regarding robotic-assisted right-side colectomy, studies and meta-analyses have also drawn similar conclusions regarding longer surgical time [22,30,41–43]. In our study, we defined the operation time from incision to closure. Significantly longer surgical times were observed for the robotic-assisted colectomy group (robot = 250 min vs. laparoscopic = 160 min, $p < 0.01$) and rectum resection group (robot = 315 min vs. laparoscopic = 223 min, $p < 0.01$). In a previously published study, in the rectum resection cohort, the operation time in the ROLLARR trial was 298.5 min in the robot group versus 261 min in the laparoscopic group [13]. Data from ACS-NSQIP revealed that the operation time was 240 min in the robot group versus 195 min in the laparoscopic group. Compared with the published data, the operation time in our robotic-assisted rectum resection group was longer. This difference in the early stage of developing robotic surgery, the operation theater crew was not familiar with the instrument setup. After the well-established protocol was developed, our operation time improved to 225 min in the colectomy group, and 271 min in the rectum resection group. Arguments on changing the definite operation time to the definition of procedure time were made as early as 2013 [28]. However, a consensus on how to define is currently lacking, causing difficulty and ambiguity in making comparisons. Compared with a previous Si system, Hill and McCormick, reported a significant reduction in operative times when performing AR by using the da Vinci Xi platform [19].

A long surgical time was identified as a risk factor in the multivariable logistic regression model for the colonic and rectal resection cohorts, but it did not influence the complication rate and LOS. Our data were consistent with the previously available evidence [22,27].

4.6. Learning Curve

Another factor that may influence the conversion rate, complication rate, and operation time is the learning curve effect. Corrigan et al. pointed out the existence of a learning curve effect influencing the result of the ROLLARR trial [14]. The number of cases of surgeons to achieve plateau performance varies from 19 to 42 [44]. In line with previous studies, in our study, maturation took 30 cases for the colectomy and rectal resection groups, and the complication rate gradually decreased after completing 23 cases [45]. Gerbaud et al. reported that surgeons experienced in laparoscopic surgery, may not cause a further increase in the morbidity rate of complications [46].

4.7. Tolerate Solid Food

In our study, the time needed to tolerate solid food and terminate urinary drainage after surgery was shorter in the robotic-assisted colectomy group and robotic-assisted rectal resection group than in the laparoscopic group (Table 3). This result was in line with published studies [23,26,28,34,47]. In the robotic-assisted colonic resection group, the time needed to tolerate solid food ranged from 3.6 days to 6.7 days in the reported study [28,34,47]. In the robotic-assisted rectum resection group, the time needed to tolerate solid food differed from 2.88 days to 3.7 days [26]. The parameters for measuring recovery of bowel function varied from "time to first flatus", "time to tolerated liquid diet", to "tolerated solid food". There is no solid consensus about how to describe the recovery of bowel function because many factors may interfere with the recovery of bowel function.

However, if the complication occurs, the un-tolerated oral intake is a clear sign. Thus, we thought that time to tolerate solid food would be an appropriate parameter for measuring bowel function recovery.

4.8. LOS

The enhanced recovery after surgery (ERAS) protocol has been proven to lower complication rates by reducing surgical stress, resulting in improved recovery for patients [26,48]. In our study, the colonic resection cohort and rectum resection cohort received the same ERAS-based standardized post-operative care including post-operation epidural pain control, minimal IV fluid amount, and early ambulation. Some of the indexes in the ERAS protocol are suitable for measuring the quality of the surgery, such as early oral intake and length of hospitalization stay. Given the involvement of many surgical or non-surgical factors, the psychiatric status of a patient can even cause differences in post-operation recovery. The LOS may be used as an integrity index for measuring a patient's recovery.

Our data showed a shorter LOS for patients who underwent robotic-assisted colonic resections (5 days for robotic vs. 8 days for laparoscopic, $p < 0.001$) and for those patients who underwent robotic-assisted rectum resection (5 days for robotic vs. 8 days for laparoscopic, $p < 0.001$). In the rectum resection cohort, the logistic regression multivariable model showed that a short time to tolerate solid food and terminate urinary drainage was a protective factor. However, in the colonic cohort, only a short time to tolerate solid food was retained as a significant protective factor. In both the colonic and rectum resection cohorts, we found that better recovery contributed to a reduced LOS. The current published literature shows that hospital LOS remains controversial in the colonic and rectum resection cohorts. In the colonic resection group, the LOS was shorter for the robotic-assisted colonic resection group than for the laparoscopy group [22,47], but other studies showed no difference in the robotic-assisted colonic resection group [28,30]. In the rectal resection group, these conflicts were observed in retrospective studies and meta-analysis studies [10,26,27,37,38,40,49].

Considering the lower complication rate, shorter time to tolerate oral intake, and LOS in the robotic-assisted group compared with those in the laparoscopic group in our study, we believe the improved recovery from surgery in the robotic-assisted group may be a result of the precise instrumental maneuvers performed during the robotic technique, which causes minimal trauma to tissues during surgery.

4.9. Limitations

Limitations to our study included but were not limited to its retrospective, nonrandomized nature. Despite a comprehensive list of potential confounders, the inclusion criteria regarded surgeons' preference for either RAL or LSC, which may have affected the results. The choice to either receive a robotic approach or laparoscopic method remains controversial [27]. Further RCTs should be able to overcome such a kind of selection bias. However, difficulties including high costs and heterogeneous surgeons' experience between multicenters may influence planning and performing RCT on robotic surgery. Although multivariate analysis was used to adjust for confounding factors when compensating bias, an inherent risk should be interpreted accordingly. A low overall complication rate, short LOS, short termination of urinary drainage and good recovery of tolerated solid food in the colectomy group and rectum resection groups were observed in the study. Age and previous abdomen surgery history in the robotic rectum resection group differed from those in the control group. Additionally, the robotic platform da Vinci Xi system was established in our hospital in late 2020, so our study included patients who underwent robotic-assisted surgery during the learning period and surgical inexperience with regard to the robotic approach. In the robotic surgery team, surgeons share surgical experience via a dual-console system and video sharing to ensure the homogeneity of the learning curve among the surgeons. Another limitation of our study was that our results came from a single-center and a relatively small sample size. Thus, the results need to be interpreted while considering its limitations regarding its retrospective, nonrandomized study design.

5. Conclusions

The new da Vinci Xi system is safe and feasible for colonic and rectal surgery with reduced complications, shorter LOS, and reliable short-term outcomes that may reflect both better functional recovery and surgical quality when compared with laparoscopic surgery.

Author Contributions: Conceptualization, Y.-L.H., M.-C.C. and F.-F.C.; methodology, M.-C.C.; software, Y.-L.H. and M.-C.C.; validation, Y.-L.H., M.-C.C. and F.-F.C.; formal analysis, M.-C.C.; resources, M.-C.C. and F.-F.C.; data curation, Y.-L.H.; writing—original draft preparation, Y.-L.H.; writing—review and editing, F.-F.C.; visualization, Y.-L.H.; supervision, F.-F.C.; project administration, Y.-L.H.; funding acquisition, F.-F.C. All authors have read and agreed to the published version of the manuscript.

Funding: Authors declare no funding received in this study.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of Taichung Veterans General Hospital (protocol code Version 1.0, (Case No. CE22367A) and date of approval: 2022/08/12).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Acknowledgments: We thank Biostatistics Task Force of Taichung Veterans General Hospital for statistical analysis support and Dean S. Dowers for language review.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Jacobs, M.; Verdeja, J.C.; Goldstein, H.S. Minimally invasive colon resection (laparoscopic colectomy). *Surg. Laparosc. Endosc.* **1991**, *1*, 144–150.
2. Nelson, H.; Sargent, D.J.; Wieand, H.S.; Fleshman, J.; Anvari, M.; Stryker, S.J.; Beart, R.W., Jr.; Hellinger, M.; Flanagan, R., Jr.; Peters, W.; et al. A comparison of laparoscopically assisted and open colectomy for colon cancer. *N. Engl. J. Med.* **2004**, *350*, 2050–2059.
3. Lorenzon, L.; La Torre, M.; Ziparo, V.; Montebelli, F.; Mercantini, P.; Balducci, G.; Ferri, M. Evidence based medicine and surgical approaches for colon cancer: Evidences, benefits and limitations of the laparoscopic vs open resection. *World J. Gastroenterol.* **2014**, *20*, 3680–3692. [CrossRef]
4. Deijen, C.L.; Vasmel, J.E.; de Lange-de Klerk, E.S.M.; Cuesta, M.A.; Coene, P.L.O.; Lange, J.F.; Meijerink, W.; Jakimowicz, J.J.; Jeekel, J.; Kazemier, G.; et al. Ten-year outcomes of a randomised trial of laparoscopic versus open surgery for colon cancer. *Surg. Endosc.* **2017**, *31*, 2607–2615. [CrossRef] [PubMed]
5. Singh, P.; Bhangu, A.; Nicholls, R.J.; Tekkis, P. A systematic review and meta-analysis of laparoscopic vs open restorative proctocolectomy. *Colorectal Dis.* **2013**, *15*, e340–e351. [CrossRef] [PubMed]
6. Weber, P.A.; Merola, S.; Wasielewski, A.; Ballantyne, G.H. Telerobotic-assisted laparoscopic right and sigmoid colectomies for benign disease. *Dis. Colon Rectum* **2002**, *45*, 1689–1694. [CrossRef] [PubMed]
7. Pigazzi, A.; Ellenhorn, J.D.I.; Ballantyne, G.H.; Paz, I.B. Robotic-assisted laparoscopic low anterior resection with total mesorectal excision for rectal cancer. *Surg. Endosc.* **2006**, *20*, 1521–1525. [CrossRef]
8. Jensen, C.C.; Madoff, R.D. Comparative effectiveness in colon and rectal cancer. *Cancer Treat. Res.* **2015**, *164*, 143–163.
9. Desouza, A.L.; Prasad, L.M.; Marecik, S.J.; Blumetti, J.; Park, J.J.; Zimmern, A.; Abcarian, H. Total mesorectal excision for rectal cancer: The potential advantage of robotic assistance. *Dis. Colon Rectum* **2010**, *53*, 1611–1617. [CrossRef]
10. Hoshino, N.; Sakamoto, T.; Hida, K.; Sakai, Y. Robotic versus laparoscopic surgery for rectal cancer: An overview of systematic reviews with quality assessment of current evidence. *Surg. Today* **2019**, *49*, 556–570. [CrossRef]
11. Clavien, P.A.; Barkun, J.; de Oliveira, M.L.; Vauthey, J.N.; Dindo, D.; Schulick, R.D.; de Santibañes, E.; Pekolj, J.; Slankamenac, K.; Bassi, C.; et al. The Clavien-Dindo Classification of Surgical Complications: Five-Year Experience. *Ann. Surg.* **2009**, *250*, 187–196. [CrossRef] [PubMed]
12. Katsuno, H.; Hanai, T.; Masumori, K.; Koide, Y.; Ashida, K.; Matsuoka, H.; Tajima, Y.; Endo, T.; Mizuno, M.; Cheong, Y.; et al. Robotic Surgery for Rectal Cancer: Operative Technique and Review of the Literature. *J. Anus Rectum Colon* **2020**, *4*, 14–24. [CrossRef]

13. Jayne, D.; Pigazzi, A.; Marshall, H.; Croft, J.; Corrigan, N.; Copeland, J.; Copeland, P.; Quirke, N.; West, T.; Rautio, N.; et al. Effect of Robotic-Assisted vs Conventional Laparoscopic Surgery on Risk of Conversion to Open Laparotomy Among Patients Undergoing Resection for Rectal Cancer: The ROLARR Randomized Clinical Trial. *JAMA* **2017**, *318*, 1569–1580. [CrossRef]
14. Corrigan, N.; Marshall, H.; Croft, J.; Copeland, J.; Jayne, D.; Brown, J. Exploring and adjusting for potential learning effects in ROLARR: A randomised controlled trial comparing robotic-assisted vs. standard laparoscopic surgery for rectal cancer resection. *Trials* **2018**, *19*, 339. [CrossRef] [PubMed]
15. Tyler, J.A.; Fox, J.P.; Desai, M.M.; Perry, W.B.; Glasgow, S.C. Outcomes and costs associated with robotic colectomy in the minimally invasive era. *Dis. Colon Rectum* **2013**, *56*, 458–466. [CrossRef] [PubMed]
16. Delaney, C.P.; Lynch, C.A.; Senagore, A.J.; Fazio, V.W. Comparison of robotically performed and traditional laparoscopic colorectal surgery. *Dis. Colon Rectum* **2003**, *46*, 1633–1639. [CrossRef]
17. Protyniak, B.; Jorden, J.; Farmer, R. Multiquadrant robotic colorectal surgery: The da Vinci Xi vs Si comparison. *J. Robot. Surg.* **2018**, *12*, 67–74. [CrossRef] [PubMed]
18. Jimenez-Rodriguez, R.M.; Quezada-Diaz, F.; Tchack, M.; Pappou, E.; Wei, I.H.; Smith, J.J.; Nash, G.M.; Guillem, J.G.; Paty, P.B.; Weiser, M.R.; et al. Use of the Xi robotic platform for total abdominal colectomy: A step forward in minimally invasive colorectal surgery. *Surg. Endosc.* **2019**, *33*, 966–971. [CrossRef]
19. Hill, A.; McCormick, J. In experienced hands, does the robotic platform impact operative efficiency? Comparison of the da Vinci Si versus Xi robot in colorectal surgery. *J. Robot. Surg.* **2020**, *14*, 789–792. [CrossRef]
20. Guillou, P.J.; Quirke, P.; Thorpe, H.; Walker, J.; Jayne, D.G.; Smith, A.M.; Heath, R.M.; Brown, J.M. Short-term endpoints of conventional versus laparoscopic-assisted surgery in patients with colorectal cancer (MRC CLASICC trial): Multicentre, randomised controlled trial. *Lancet* **2005**, *365*, 1718–1726. [CrossRef]
21. Rottoli, M.; Bona, S.; Rosati, R.; Elmore, U.; Bianchi, P.P.; Spinelli, A.; Bartolucci, C.; Montorsi, M. Laparoscopic rectal resection for cancer: Effects of conversion on short-term outcome and survival. *Ann. Surg. Oncol.* **2009**, *16*, 1279–1286. [CrossRef] [PubMed]
22. Dolejs, S.C.; Waters, J.A.; Ceppa, E.P.; Zarzaur, B.L. Laparoscopic versus robotic colectomy: A national surgical quality improvement project analysis. *Surg. Endosc.* **2017**, *31*, 2387–2396. [CrossRef] [PubMed]
23. Gass, J.-M.; Daume, D.; Schneider, R.; Steinemann, D.; Mongelli, F.; Scheiwiller, A.; Fourie, L.; Kern, B.; von Flüe, M.; Metzger, J.; et al. Laparoscopic versus robotic-assisted, left-sided colectomies: Intra- and postoperative outcomes of 683 patients. *Surg. Endosc.* **2022**, *36*, 6235–6242. [CrossRef] [PubMed]
24. Panteleimonitis, S.; Pickering, O.; Ahmad, M.; Harper, M.; Qureshi, T.; Figueiredo, N.; Parvaiz, A. Robotic rectal cancer surgery: Results from a European multicentre case series of 240 resections and comparative analysis between cases performed with the da Vinci Si and Xi systems. *Laparosc. Endosc. Robot. Surg.* **2020**, *3*, 6–11. [CrossRef]
25. Beltzer, C.; Knoerzer, L.; Bachmann, R.; Axt, S.; Dippel, H.; Schmidt, R. Robotic Versus Laparoscopic Sigmoid Resection for Diverticular Disease: A Single-Center Experience of 106 Cases. *J. Laparoendosc. Adv. Surg. Tech. A* **2019**, *29*, 1451–1455. [CrossRef]
26. Asklid, D.; Ljungqvist, O.; Xu, Y.; Gustafsson, U.O. Short-term outcome in robotic vs laparoscopic and open rectal tumor surgery within an ERAS protocol: A retrospective cohort study from the Swedish ERAS database. *Surg. Endosc.* **2021**, *274*, e1218–e1222. [CrossRef]
27. Crippa, J.; Grass, F.; Dozois, E.J.; Mathis, K.L.; Merchea, A.; Colibaseanu, D.T.; Kelley, S.R.; Larson, D.W. Robotic Surgery for Rectal Cancer Provides Advantageous Outcomes Over Laparoscopic Approach: Results From a Large Retrospective Cohort. *Ann. Surg.* **2021**, *274*, e1218–e1222. [CrossRef]
28. Helvind, N.M.; Eriksen, J.R.; Mogensen, A.; Tas, B.; Olsen, J.; Bundgaard, M.; Jakobsen, H.L.; Gögenür, I. No differences in short-term morbidity and mortality after robot-assisted laparoscopic versus laparoscopic resection for colonic cancer: A case-control study of 263 patients. *Surg. Endosc.* **2013**, *27*, 2575–2580. [CrossRef]
29. Duan, B.-S.; Zhao, G.-H.; Yang, H.; Wang, Y. A Pooled Analysis of Robotic Versus Laparoscopic Surgery for Colon Cancer. *Surg. Laparosc. Endosc. Percutan Tech.* **2016**, *26*, 523–530. [CrossRef]
30. Solaini, L.; Bazzocchi, F.; Cavaliere, D.; Avanzolini, A.; Cucchetti, A.; Ercolani, G. Robotic versus laparoscopic right colectomy: An updated systematic review and meta-analysis. *Surg. Endosc.* **2018**, *32*, 1104–1110. [CrossRef]
31. Fleming, C.A.; Westby, D.; Ullah, M.F.; Mohan, H.M.; Sehgal, R.; Bolger, J.C.; O'leary, D.P.; McNamara, E.; Korpanty, G.; El Bassiouni, M.; et al. A review of clinical and oncological outcomes following the introduction of the first robotic colorectal surgery programme to a university teaching hospital in Ireland using a dual console training platform. *J. Robot. Surg.* **2020**, *14*, 889–896. [CrossRef]
32. Huang, Y.M.; Huang, Y.J.; Wei, P.L. Outcomes of robotic versus laparoscopic surgery for mid and low rectal cancer after neoadjuvant chemoradiation therapy and the effect of learning curve. *Medicine* **2017**, *96*, e8171. [CrossRef]
33. de Jesus, J.P.; Valadão, M.; Araujo, R.O.d.C.; Cesar, D.; Linhares, E.; Iglesias, A.C. The circumferential resection margins status: A comparison of robotic, laparoscopic and open total mesorectal excision for mid and low rectal cancer. *Eur. J. Surg. Oncol.* **2016**, *42*, 808–812. [CrossRef]
34. Trastulli, S.; Cirocchi, R.; Desiderio, J.; Coratti, A.; Guarino, S.; Renzi, C.; Corsi, A.; Boselli, C.; Santoro, A.; Minelli, L.; et al. Robotic versus Laparoscopic Approach in Colonic Resections for Cancer and Benign Diseases: Systematic Review and Meta-Analysis. *PLoS ONE* **2015**, *10*, e0134062. [CrossRef]

35. Prete, F.P.; Pezzolla, A.; Prete, F.; Testini, M.; Marzaioli, R.; Patriti, A.; Jimenez-Rodriguez, R.M.; Gurrado, A.; Strippoli, G.F.M. Robotic Versus Laparoscopic Minimally Invasive Surgery for Rectal Cancer: A Systematic Review and Meta-analysis of Randomized Controlled Trials. *Ann. Surg.* **2018**, *267*, 1034–1046. [CrossRef]
36. Li, X.; Wang, T.; Yao, L.; Hu, L.; Jin, P.; Guo, T.; Yang, K. The safety and effectiveness of robot-assisted versus laparoscopic TME in patients with rectal cancer: A meta-analysis and systematic review. *Medicine* **2017**, *96*, e7585. [CrossRef]
37. Sun, Y.; Xu, H.; Li, Z.; Han, J.; Song, W.; Wang, J.; Xu, Z. Robotic versus laparoscopic low anterior resection for rectal cancer: A meta-analysis. *World J. Surg. Oncol.* **2016**, *14*, 61. [CrossRef]
38. Huang, Y.-J.; Kang, Y.-N.; Huang, Y.-M.; Wu, A.T.; Wang, W.; Wei, P.-L. Effects of laparoscopic vs robotic-assisted mesorectal excision for rectal cancer: An update systematic review and meta-analysis of randomized controlled trials. *Asian J. Surg.* **2019**, *42*, 657–666. [CrossRef] [PubMed]
39. Xiong, B.; Ma, L.; Huang, W.; Zhao, Q.; Cheng, Y.; Liu, J. Robotic versus laparoscopic total mesorectal excision for rectal cancer: A meta-analysis of eight studies. *J. Gastrointest. Surg.* **2015**, *19*, 516–526. [CrossRef] [PubMed]
40. Cui, Y.; Li, C.; Xu, Z.; Wang, Y.; Sun, Y.; Xu, H.; Li, Z.; Sun, Y. Robot-assisted versus conventional laparoscopic operation in anus-preserving rectal cancer: A meta-analysis. *Ther. Clin. Risk Manag.* **2017**, *13*, 1247–1257. [CrossRef] [PubMed]
41. Chang, Y.S.; Wang, J.X.; Chang, D.W. A meta-analysis of robotic versus laparoscopic colectomy. *J. Surg. Res.* **2015**, *195*, 465–474. [CrossRef] [PubMed]
42. Rondelli, F.; Balzarotti, R.; Villa, F.; Guerra, A.; Avenia, N.; Mariani, E.; Bugiantella, W. Is robot-assisted laparoscopic right colectomy more effective than the conventional laparoscopic procedure? A meta-analysis of short-term outcomes. *Int. J. Surg.* **2015**, *18*, 75–82. [CrossRef]
43. Rausa, E.; Kelly, M.E.; Asti, E.; Aiolfi, A.; Bonitta, G.; Bonavina, L. Right hemicolectomy: A network meta-analysis comparing open, laparoscopic-assisted, total laparoscopic, and robotic approach. *Surg. Endosc.* **2019**, *33*, 1020–1032. [CrossRef]
44. Pernar, L.I.M.; Robertson, F.C.; Tavakkoli, A.; Sheu, E.G.; Brooks, D.C.; Smink, D.S. An appraisal of the learning curve in robotic general surgery. *Surg. Endosc.* **2017**, *31*, 4583–4596. [CrossRef] [PubMed]
45. Symer, M.M.; Sedrakyan, A.; Yeo, H.L. Case Sequence Analysis of the Robotic Colorectal Resection Learning Curve. *Dis. Colon Rectum* **2019**, *62*, 1071–1078. [CrossRef]
46. Gerbaud, F.; Valverde, A.; Danoussou, D.; Goasguen, N.; Oberlin, O.; Lupinacci, R.M. Experience With Transitioning From Laparoscopic to Robotic Right Colectomy. *JSLS* **2019**, *23*, e2019.00044. [CrossRef]
47. Lim, S.; Kim, J.H.; Baek, S.-J.; Kim, S.-H.; Lee, S.H. Comparison of perioperative and short-term outcomes between robotic and conventional laparoscopic surgery for colonic cancer: A systematic review and meta-analysis. *Ann. Surg. Treat. Res.* **2016**, *90*, 328–339. [CrossRef] [PubMed]
48. Gustafsson, U.O.; Scott, M.J.; Hubner, M.; Nygren, J.; Demartines, N.; Francis, N.; Rockall, T.A.; Young-Fadok, T.M.; Hill, A.G.; Soop, M.; et al. Guidelines for Perioperative Care in Elective Colorectal Surgery: Enhanced Recovery After Surgery (ERAS®) Society Recommendations: 2018. *World J. Surg.* **2019**, *43*, 659–695. [CrossRef]
49. Yang, Y.; Wang, F.; Zhang, P.; Shi, C.; Zou, Y.; Qin, H.; Ma, Y. Robot-assisted versus conventional laparoscopic surgery for colorectal disease, focusing on rectal cancer: A meta-analysis. *Ann. Surg. Oncol.* **2012**, *19*, 3727–3736. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.